Toward a Better Understanding of Ocean-Wave-Typhoon Interactions in the Western Pacific Ocean

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LONG-TERM GOALS

This project investigates the interplay among typhoon-strength winds, ocean surface waves and upper-ocean circulation during and after typhoon passages over the western Pacific Ocean and around the island of Taiwan.

OBJECTIVES

We use three numerical models and calibrate them against continuous measurements of ocean currents, temperature, wave heights and turbulence intensities from several open ocean moorings in the western Pacific. Through these calibrations, we will learn how to better represent winds, ocean currents and waves under typhoon-strength wind conditions in the western Pacific Ocean.

APPROACH

For the atmosphere, we use the Navy's operational West Pacific atmospheric model (COAMPS) and JPL wind to drive ocean waves and upper ocean circulation. For ocean waves, we use SWAN (Booji et al.,1999; Ris et al., 1999) to generate them and calibrate simulated results against observed wave heights from moorings. For the ocean circulation, we invoke the Naval Research Laboratory's East Asian Seas Nowcast/Forecast System (EASNFS, Ko et al., 2008) to simulate upper-ocean response. Resolutions of these models are sufficiently high. Mooring observations maintained by Taiwanese colleagues were from 3 subsurface moorings that measured upper ocean (top 500 m) currents and 4 ATLAS-like moorings that measured upper ocean temperature. Subsurface moorings are at stations SA1 (127.53°E, 20.37°N), SA2 (123.27°E, 21.23°N) and SA3 (123.63°E, 22.00°N). Four ATLAS-like moorings are at stations A1 (127.64°E, 20.34°N), A2 (123.25°E, 21.07°N), A3 (126.03°E, 18.52°N) and A4 (123.84°E, 22.13°N). Through calibration and analysis of the three models and observations, we intend to identify crucial oceanic and wave processes that regulate typhoon's strength and path.

Key individuals participating in this work include Shenn-Yu Chao as the lead PI and Dong-Shan Ko of NRL, who will maintain EASNFS and provide wind products. Ya-Ting Chang, visiting on as-needed basis from Institute of Oceanography, National Taiwan University, serves as the liaison between our modeling components and Taiwanese observation components. Her efforts along this line of investigation will constitute the bulk of her Ph.D. dissertation.

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WORK COMPLETED

Focusing on 2009, there were two typhoons, one tropical storm and one tropical depression passing by the study area. Among the four, typhoon Lupit (2009) had the closest encounter with temperature strings at stations A1, A2 and A3 (Figure 1). In particular, this once-declared category-5 typhoon Lupit ran over buoy A1 with its eye and skirted by stations A3 with its eye wall on the left hand side of its track when it was weakening from category 3 to 2. Sensors along the temperature strings under buoys generally worked well except for a few failures far in between. Highest wind speed of 60 m/s and lowest air pressure of 941 mb were recorded under the eye. Essential findings are summarized below.

RESULTS

(1) As Lupit's eye encroached, the mixed-layer cooled gradually while the upper thermocline was warmed by downwelling. As Lupit's eye moved away, wind relaxation and upwelling came into play. Upper ocean was cooled especially in the thermocline. Thereafter upper ocean temperature oscillated slightly above the inertial frequency. In terms of upward isotherm displacement, upwelling amounted to 37 m at the station (A1) visited by Lupit's eye and 27 m at the station (A3) skirted by the eye wall. However, the largest temperature drop in the thermocline was almost the same at A1 and A3; the latter had weaker stratification and was preconditioned by a cold eddy.

(2) Our mooring locations were in the open ocean setting of the western tropic Pacific. With or without typhoons, variations of upper ocean (top 360 m) heat content generally correlated reasonably well with satellite-measured sea level anomaly. Figure 2 shows such tight relationships at stations A1, A2 and A3 from March 2009 to April 2010. This tight relationship put the potential involvement of westward propagating eddies in proper perspective. Sizable departures from good correlations did exist. For example, during spring 2009, we had observed two cooling events induced by the passages of cold fronts; ocean cooling in those occasions was from the surface down. Their shallowness decreased the corelation between sea level and upper ocean heat content. Leaving cold front passages aside, intermittent cooling and sudden warming events were often caused by the passage of cold and warm eddies.

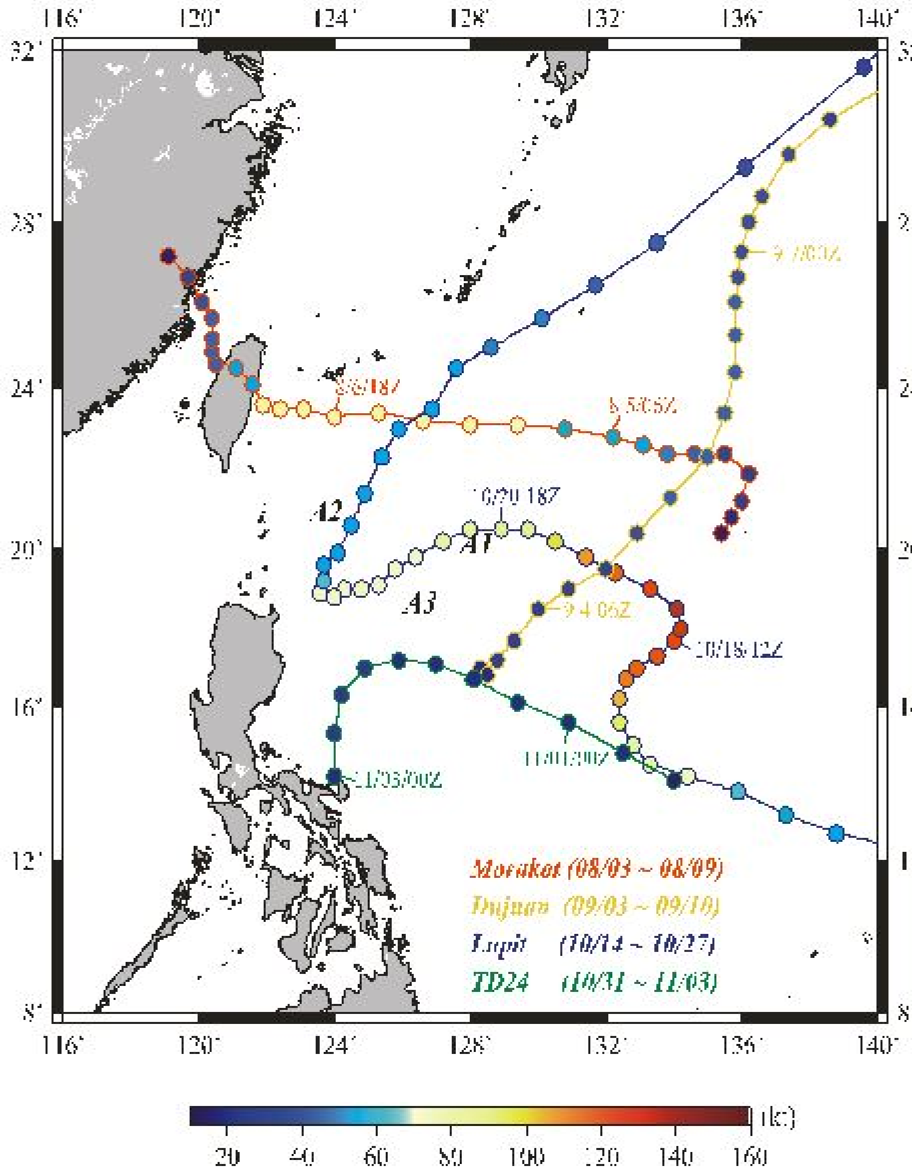

Figure 1 Three buoy locations (A1, A2 and A3). Superimposed are color-differentiated tracks of category-1 typhoon Morakot, category-5 typhoon Lupit, severe tropical storm Dujuan and tropical depression TD24 in 2009. Their strengths are dotted and color-differentiated every six hours.

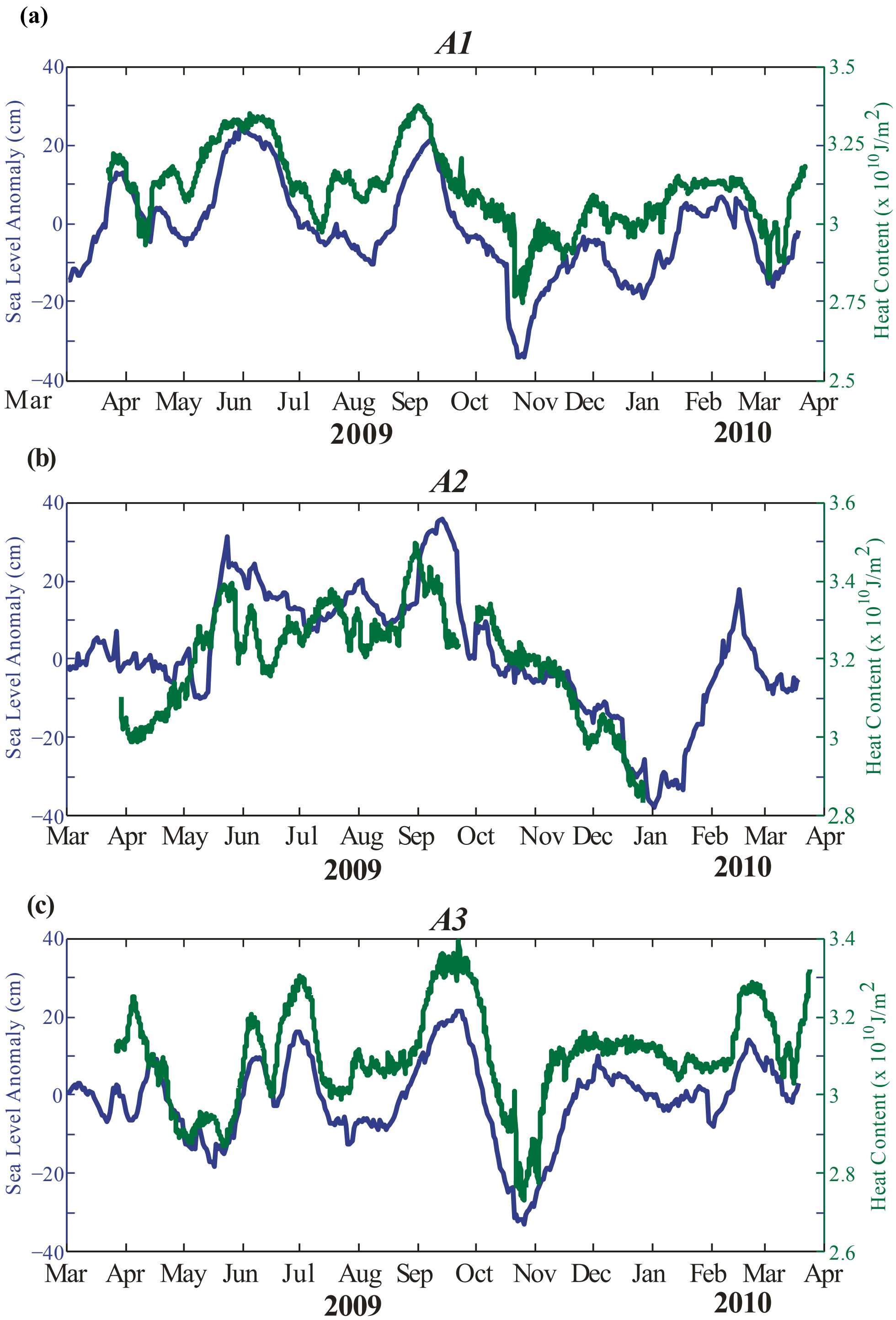

Figure 2 The depth-integrated (1-360m) upper ocean heat content (green lines) and satellite-derived sea level anomaly (blue lines) at stations (a) A1, (b) A2 and (c) A3.

(3) Relevant issues such as Lupit-induced cold wake evolution, post-Lupit near-inertial oscillation and its its super-inertial extension, inherited intermittency and underlying reasons are still in the final stage of investigation.

(4) Beyond the core objective of this project, coorporations with other ITOP investigators in related subjects have resulted in three publications as listed in the publications section below.

IMPACT/APPLICATIONS

Under typhoon strength winds, the interplay among winds, upper ocean currents and surface gravity wave fields is quite complex. To a certain extent, the wave field alters the ocean mixed layer, which in turn regulates the amount of upper ocean heat content released to the atmosphere. Thus, a more realistic wave field may ultimately produce better typhoon strength and track forecasts. In this light, it seems necessary to include the upper ocean currents in order to better forecast typhoons after they come into contact with the Kuroshio and its adjacent eddies. Further, a more realistic wave field may also improve upper ocean circulation and lead to better regional ocean models. Taking advantage results from IOP-2010, our investigation along this line will advance our understanding.

RELATED PROJECTS

None in this year.

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